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PLANT-BREEDING

By H. J. Webber

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CITRICULTURE

PLANT-BREEDING

BY

HERBERT J. WEBBER

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~~rich and so treating it that it will hold moisture. *Plantago Coronopus*, the Bucks-horn Plantain, native to Europe, Asia and North Africa, is sometimes eaten as a pot-herb (see p. 697). It is a low perennial, with linear-lanceolate often pinnatifid leaves. It is not in the American trade. *P. cordata*, of the eastern United States, is offered by one or two dealers in native plants as a subject for colonizing in bogs and margins of ponds. It is perennial, with a stout rootstock, large cordate-orbicular shining leaf-blades, and a slender spike rising 1–2 ft. high and bearing small pinkish flowers with exserted style and stamens. *P. major* (Fig. 1838) is a very common dooryard weed. There are about 20 native or naturalized species in North America. Plantago is the typical genus of the *Plantaginaceæ*, a family that contains two other genera, both monotypic.—Littorella in Europe and northern North America, and Bougueria in the Andes of Peru and Chile.~~

~~L. H. B.~~

1838. Spike of Plantago major—common Plantain. Nat. size.

~~**PLANTAIN.** See *Plantago* and *Musa*.~~

~~**PLANTAIN LILY.** *Funkia*.~~

~~**PLANTAIN, RATTLESNAKE.** *Hieracium venosum*.~~

~~**PLANTAIN, WILD.** *Heliconia Bihai*.~~

PLANT-BREEDING. Practical agriculturists the world over have long recognized that animals can be greatly improved by intelligent breeding, but it is only within the last century that it has come to be recognized that plants can be improved in the same way. Even yet some of the fundamental principles of plant-breeding are not generally understood and require to be demonstrated experimentally. Within recent years, however, general interest has been awakened in the subject, particularly in this country, and doubtless results of the greatest interest will soon be attained.

Practical plant-breeding may be said to have begun with the work of Thomas Andrew Knight and Jean Baptiste Van Mons in the early part of the nineteenth century. Knight was the first to show the practical value of hybridization in the production of new sorts and races. As early as 1806 he wrote: "New varieties of every species of fruit will generally be better obtained by introducing the farina of one variety of fruit into the blossoms of another than by propagating from a single kind." The other most important factor of plant-breeding, that of selection, was first established by Van Mons, a Belgian horticulturist who worked mainly with pears. (See Essay 5, "Survival of the Unlike," Bailey.) Since this time many investigators have given time and thought to the ways in which plants may be improved, until at present we have established a fairly definite system which may be followed, with slight variation, in the amelioration and improvement of any plant.

The plant-breeder must first of all recognize that a thorough knowledge of the plant he desires to improve is of primary importance. The time for haphazard experimenting has long since gone by, and the experimenter may simply waste his time if his efforts are not well directed. If it is apples or wheat that he desires to improve, all of the varieties of apples and wheat should be studied and their qualities recognized. The experimenter should always have in view a definite improvement which he wishes to obtain, and the varieties which exhibit this feature in the highest degree should be selected for the work. If working from the utilitarian standpoint, the desirability of having a definite aim in view can hardly be overestimated, as it is only in this way that the breeder can be guided in his selection of the parent stock or stocks.

Systematic plant-breeding includes two processes largely distinct in their nature: (1) The production of variations, and (2) the fixation and augmentation of desirable variations by methodical selection.

In order to improve a plant it must be induced to vary in the required direction. If this variation is brought about by some environmental change the same conditions are maintained through another generation, and the plants showing the greatest variation in the required direction are again selected, thus gradually leading to a progressive improvement in the character desired. If the variation is produced by hybridization it must be fixed and rendered hereditary by a similar process of selection. Thus, whether breeding by selection alone or by hybridization, these two factors of breeding enter into the process.

Variations, How Produced.—In general, plants reproduce their main characters unchanged. The stability of the races of our cultivated plants and natural species depends upon this law of heredity, which has been expressed in the aphorism "like produces like." Plants, however, are not fixed and stable beings, but are eminently plastic and variable. Every individual differs from every other individual in some way, just as every individual animal differs from every other individual of the same race. These individual variations which enable us to recognize one plant from another, or one animal from another, and which are inherent in the being itself and not, so far as can be determined, dependent upon environment, are what Darwin termed "indefinite variations," and are now generally known as "congenital variations." If we examine a row of nursery trees of apple or peach we find that every individual may be clearly recognized by some distinctive character. Some trees grow erect and columnar, some low and spreading, some branch low, some high, some have large leaves, some small leaves, and by a careful examination numerous other distinguishing characters can be found. It is on these individual variations that the improvement of plants by selection mainly depends.

It has been found by breeders of both plants and animals that individuals vary greatly in the power of transmitting their characters to their offspring, and this is one of the most important factors in plant-breeding. As an illustration, ten individual cotton plants may be selected which produce an exceptionally long lint of comparatively the same character. If the seeds from each of these ten select plants are planted separately it will be found that the ten plants vary greatly in their ability to transmit this character of producing long lint to their offspring. The entire progeny of one plant may revert and produce a much shorter staple than the parent form. On the other hand, one of the original ten plants may have the power of inheritance strongly developed and transmit to the great majority of its progeny the quality of producing long lint. It is to the progeny, then, of this individual that the breeder must look in order to fix a new race of long-staple cotton. The strength of the hereditary tendency is thus of the greatest importance to the breeder.

Another form of variation probably important to the plant-breeder is that caused as a direct result of environment and termed by Darwin definite variation, because all plants subject to the same environment tend to vary in the same direction. As an illustration, plants removed from a low altitude to a high altitude become dwarfed in stature and the flowers become larger and usually brighter colored. Transferring the plant to the seacoast and growing it under maritime conditions usually results in the leaves becoming thicker and the whole plant more succulent. If such plants are transferred back to the interior, away from all effects of the sea, the next year they usually, if not always, revert entirely to their original characters. If, however, they are grown in a maritime region for several generations and the seed is selected every year from the most succulent individuals, it is believed that a succulent sort may be originated more quickly than in any other way.

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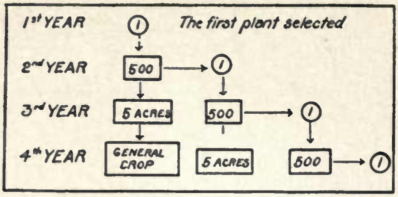
How valuable this factor of environment is in the origination of newly cultivated sorts yet remains to be demonstrated scientifically, but some practical plant-breeders contend that it is a factor of very great importance.

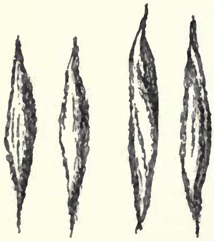


1839. Diagram illustrating method of selecting cotton.

Occasionally individuals "sport," as gardeners say, and plants entirely different from the type of the race are produced. These variations are usually very marked ones and no definite cause for their appearance is yet known. Many valuable races of cultivated plants owe their origin to variation of this sort. For instance, the Cupid type of the sweet pea, a dwarf race, originated as a seedling sport from the Emily Henderson, an ordinary tall sort, and certain other sweet peas, the writer is informed, show a tendency to sport in this way. Another variation of similar kind is the change in character of certain parts or branches of individuals, known as bud-sporting. Bud-sports have proved particularly valuable in producing new sorts of chrysanthemum and other plants cultivated for their flowers. There appears to be no way in which the breeder can induce seedling- or bud-sports, and the only course seems to be to watch carefully for their occurrence and be ready to utilize them whenever they appear.

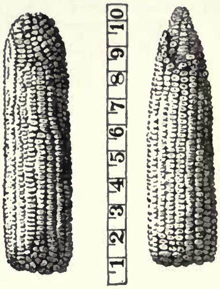
The most fertile way of securing variations is by the intermingling of species and varieties by hybridization. By blending distinct types of different species or races in this way, individuals of almost any grade of intermediacy between the two parents can be obtained and those having valuable combinations of characters selected and sometimes fixed into stable races. Crossing in general is probably the most active agency in procuring variation, and is thus of the highest importance to the plant-breeder, inasmuch as the production of the initial variation of a desired kind and in a desired direction is the most difficult achievement.

Improvement by Selection.—Improvement by selection depends upon the principle of gradually augmenting a quality by selecting seed each year from that individual which by comparison with numerous other individuals is found to exhibit the character desired in the greatest perfection or highest degree. By this constant selection of seed from the best individual, it has been found that the desired quality can be secured in more and more marked degree the longer the selection is continued. It is to this cumulative power of selection that the great improvement in many of our cultivated plants is due, and, in general, selection may be considered a fundamental factor in the successful cultivation of any crop, as it is necessary not only to improve a race but to retain it true to type and in vigorous productive condition.



1840. Improvement of Sea Island Cotton by selection. Ordinary type on left, and selected type on right.

The most marked instance known to the writer of the improvement of a plant by selection alone and the dependence of an entire industry on this factor, is that of the sea island cotton. Every successful grower of sea island cotton selects his seed each year with the greatest care, and pursues year after year a definite process of continuous selection. In beginning selection, the general crop is examined and a number of individuals selected which seem from general appearance, vigor, productiveness, etc., to be superior plants. These superior plants are then subjected to a very critical examination as to (1) vigor, (2) productiveness, (3) season, (4) covering and size of seed, (5) character of staple, etc. Under the last heading, "character of staple," attention is given to (*a*) length, (*b*) strength, (*c*) silkiness, (*d*) fineness, (*e*) uniformity of length and (*f*) proportion of lint to seed. etc. Finally, considering all of the above points carefully, the individual which is found to be superior to all others is selected. The seed from this is saved and planted the next year in a select patch and will usually yield some 500 individuals.



1841. Improvement of corn by selection.

Boone County White corn on left, and original type from which it was developed by selection on right.

The second year a single superior plant is selected with the same care from among the 500 plants grown from the seed of the plant selected the first year. The seed of the remaining individuals of the 500 plants is retained to plant a special seed patch the third year.

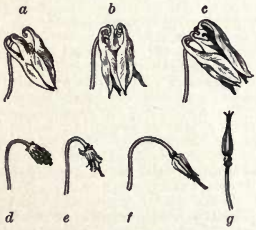
The third year the seed of the specially selected plant of the preceding year is grown by itself, producing some 500 plants, from among which a single superior individual is again selected. The seed of the remaining 500 plants is again retained to plant a special seed patch the fourth year. Further than this, in the third year the seed of the 500 plants grown the previous year is planted by itself and will produce a patch of some 5 acres in extent, which will yield sufficient seed to plant the general crop in the fourth year of the selection. (Compare Fig. 1839.) In succeeding years this policy is continued, the general crop being grown continuously from seed of a higher and higher grade of selection. Under this continuous selection the quality and length of the staple has been continuously improved (Fig. 1840), and the yield increased, so that the growers today are producing more cotton than ever before and of a better quality. Corn (Fig. 1841), wheat, and very many of our races of other cultivated plants have been improved in a similar manner, and many of our most valuable races to-day are simply types gradually ameliorated through years of continuous selection.

In a similar manner selection may be used to improve any character of a plant, as the shape or color of a flower, acidity of the fruit, sugar content of the root (as in the beet), protein content of the seed (as in corn and wheat), etc. The necessity of intelligent selection of plants from which seed is to be taken can hardly be overestimated.

In all of our orchard fruits selection has played a most important part, though here the process is slightly different, as the selection is usually limited to a single generation, the best individual among many seedlings being selected and propagated by buds or grafts so that further selection to fix and retain its qualities are unnecessary. In this way was produced the famous Concord grape, the Dana Hovey pear, the Wealthy apple, etc. It must not be understood, however, that continuous selection would not give valuable results among orchard fruits also. Some of our good select seedling varieties are seedlings of select seedlings, and the process is thus a continuous one, though carried on largely by different experimenters owing to the long time required to secure fruits.

The character of the individual as a whole is a factor of prime importance in selection, and should be clearly recognized by every one striving for improved or pedigree plants. The aim should not be to select the single best fruit, but to select fruit from the best individual plant. If one is selecting to decrease the number of seed he would probably entirely fail should he depend upon examining a number of fruits without reference to the plants on which they grew, and selecting that one for propagation which was found to contain the fewest seed. He should examine the fruit on numerous trees, and then take seed for planting from that tree which by the examination of many fruits is found to show the most decided general tendency toward seedlessness.

Limitations of Selection.—Selection is by many horticulturists considered to have been the most important factor in the development of our cultivated plants, and some go so far as to assert that all other factors are of minor importance. Both crossing and selection, however, have their definite and distinct places in any rational system of plant-breeding. When used alone in the improvement of plants, selection depends upon the adding up of small, insignificant variations through many generations, which in the end may possibly result in marvelous differences; but by this method the breeder has no way to force the change, and must be satisfied with slight variation and long-continued selection. When marked changes and new creations are desired it is to crossing or to chance sports that attention must be directed.

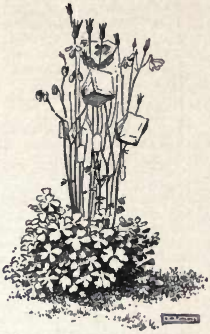


1842. Aquilegia flowers, illustrating the process of emasculation.

a, mature bud showing stage which should be selected for emasculation; *b*, similar bud with the tips of the corolla pried apart and the stamens removed; *c*, a bud opened naturally, too old to operate on; *d*, a bud of the stage shown in *a* and *b*, with corolla removed to show the internal organs; *e*, a bud the same as in *d*, but with the stamens removed; *f*, the same as *e*, but older, at the age when pollination normally takes place; *g*, pistil shortly after fecundation, the remnants of the stamens having fallen away.

IMPROVEMENT BY MEANS OF CROSSING.—Aside from selection, crossing has played the most important role in the formation of the varieties and races of our cultivated plants, but the results obtained are in many cases closely connected with selection. In the production of new and novel races it is to the crossing of markedly different species or races that the breeder must look. In this way plants may be obtained combining the good qualities of two distinct sorts, with an elimination of the undesirable features. In plants which are propagated by vegetative parts, such as buds, grafts, cuttings, etc., a desirable variation obtained by crossing may be propagated directly without further improvement. This is the case in apples, pears, oranges, and all orchard fruits. In the case of plants propagated by seed, however, a valuable hybrid must be inbred and selected for several generations until a fixed type is produced.

The process of crossing or hybridizing plants is neither difficult nor mysterious. It is simply necessary to recognize that plants, like animals, bear male and female organs. In plants, however, the male and female elements are most commonly borne on the same individual and in the same flower. In some cases, as in the castor bean, corn, etc., both sexes are borne on the same plant but in different flowers, while in other cases, as in the date palm, hemp, box elder, etc., the sexes are on different plants.



1843. Plant of Aquilegia with flowers covered with bags in hybridization work.

If the plant to be operated on has the stamens and pistils (male and female organs) in the same flower, buds must be selected and the stamens removed before they burst and discharge the pollen. This is necessary in order to prevent self-fertilization. In some instances, as in the case of the columbine, this can be done very easily by simply selecting a bud just before it opens (Fig. 1842) and prying the tips of the petals apart so that the stamens may be pulled off with small pincers or forceps. The bud should then be inclosed in a small paper bag until the pistil matures normally, when the bag may be removed and the pollen dusted over the pistil (female organ). After this the bag must again be put over the flower to prevent other pollen from being brought in by insects, etc. Fig. 1843. In some cases the pollen may be placed on the immature pistil without injury when the flower is emasculated, and this is a great saving of time when it can be done. However, in experiments conducted by C. P. Hartley, of the U. S. Department of Agriculture, it has been demonstrated that in some plants the pollination of immature pistils produces injury and thus cannot be practiced in all cases.

In some instances, as in the apple, pear, cotton, etc., it is difficult to pry the petals apart to remove the stamens, and in such cases the corolla may be cut off without injury, in this way exposing the organs so that the stamens can be easily removed (Fig. 1844).

In striving to secure a certain combination of the good characters of any two sorts, very numerous crosses between them should be made in order to furnish the breeder greater range of selection. Indeed at every step the success of the plant-breeder depends on handling large numbers. True, the desired variation may be secured in a small batch of crosses, but the chance of success is increased in proportion to the number handled. In his experiments Burbank has found that in peaches about one desirable variety of superior excellence is obtained from each 1,000 seedlings tested, while in raspberries and blackberries only about one sort in 20,000 has proved to be worthy of retention.

In the crossing of races and species the hybrids in the first generation are usually nearly alike, exhibiting in general the same intermediate characters. In the second generation of these hybrids, however, there is almost invariably greater variation, and it is usually from the plants of this generation that the most valuable

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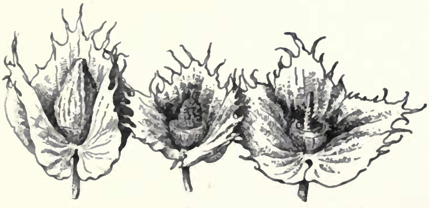
types can be selected. It is thus important that the hybrids of the first generation should be inbred with their own pollen or with pollen of the hybrids of the same combination, and numerous individuals of the second generation obtained in which plants showing the desired combination of characters are more likely to be found.

One of the most prominent characters of crosses is their extreme vigor, which is particularly marked in racial and specific hybrids where the parents are widely distinct in characters (Fig. 1845). In crosses of closely related sorts, which are reproduced by buds, cuttings, slips, etc., and which do not ordinarily remain true to type when propagated by seed, the increase in vigor is not commonly so marked.

Sterility, which is a common character of hybrids of very distinct species and races, may prove a detriment in certain cases; but it is seldom that all of the hybrids of any combination are completely sterile, and in most instances of this sort complete fertility can probably be secured by selection.

The improvements which can be secured by means of crossing are almost innumerable, and many of them, so far as we are informed, can be secured in no other way. Such is the production of fragrant varieties from odorless types as has been accomplished in the case of pansies, and the blending and changing of colors of flowers and fruits. Increased hardiness and adaptability to growth in warmer climates might possibly be secured by simple selection through a long series of years; but they can doubtless be most quickly secured by crossing tender and hardy sorts or species, when plants can be obtained which possess these opposite qualities.

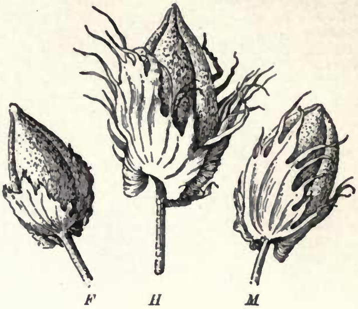
Fixation of Crosses.—In plants which are propagated by vegetative parts no fixation is necessary, but in those which are propagated by seed, all crosses that are found to possess desirable qualities must be fixed by selection into stable races reproducing these qualities true. Usually, a large majority of the progeny of a cross will revert toward one of the parents, and may not show the characters desired. In order to render the desired qualities hereditary, the cross must be inbred with its own pollen or the pollen of another cross of the same parentage which exhibits the same characters, and a large number of plants grown from the seed thus produced. These plants must then be carefully examined and individuals selected for further work which have reproduced the desired characters in the highest degree. These individuals must be again inbred and the process continued for several generations until all of the plants are reproduced true to the desired type. This, in most cases, requires from five to six generations of careful selection. The time used in selecting to fix the type is by no means lost, as meanwhile careful attention can be given to increasing the fruitfulness so that this factor also may be greatly improved.



1844. Cotton flowers, illustrating the process of emasculation.

a, mature bud showing the stage which should be selected for emasculation; *b*, a similar bud with the corolla cut off ready to emasculate; *c*, a similar bud with the stamens removed,—emasculated.

THE SELECTION OF VEGETATIVE PARTS.—Within recent years some attention has been given to the improvement of plants by the selection of buds, cuttings, etc., and the results obtained by certain practical investigators indicate that much may be accomplished in this way. In orchard fruits, carnations, violets, potatoes, etc., careful attention should thus be given to the buds or cuttings used in propagation. By a careful selection of violet cuttings from those plants which were found to produce the greatest number of good flowers, P. H. Dorsett has greatly increased the average yield of his plants and believes that an increased yield of nearly 100 per cent is perfectly possible by careful attention to this factor alone. Here, again, it is not increased yield merely which can be improved, but various other qualities as well.



1845. Increase in size of cotton bolls caused by hybridization.

F, Sea island cotton used as the female parent; *H*, hybrid; *M*, Klondike, a variety of upland cotton used as the male parent.

The literature of plant-breeding is mainly scattered through periodicals and is difficult of access. The principal work treating the subject in a general way is Professor Bailey's "Plant-Breeding" (The Macmillan Company, New York, 1895). The following are a few of the most important general papers: "The Production et Fixation des variétés dans les végétaux," by E. A. Carrière, Paris, 1865; "Die Pflanzenmischlinge," by W. O. Focke, Berlin, 1881; "A Selection from the Physiological and Horticultural Papers of Thomas Andrew Knight, published in the Transactions of the Royal and Horticultural Societies," London, 1841; "Hybrids and their Utilization in Plant-Breeding," by W. T. Swingle and H. J. Webber; Year-book, U. S. Department of Agriculture, 1897; "Sur la Production et la Fixation des Varietes dans les Plantes d'Ornement," by Jean Baptiste Verlot, Paris, 1865; "The Improvement of Plants by Selection," Yearbook, U. S. Department of Agriculture, 1898; "Hybrid Conference Report," Journal Roy. Hort. Society, vol. xxiv, April, 1900; "Survival of the Unlike," by Bailey.

HERBERT J. WEBBER.

PLANT CELLARS will be treated under *Winter Protection.*

PLÁTANUS (its ancient Greek name). *Platanaceæ.* PLANE-TREE. BUTTONWOOD. Ornamental deciduous trees with alternate, petioled, rather large, palmately lobed lvs. and small greenish flowers in globular, solitary or racemose, slender-stalked and drooping heads, followed by similar heads of fruits remaining on the branches during the winter. The smooth, light-colored often almost creamy white bark of the branches and limbs, usually mottled by darker blotches of the older bark, which peels off in large thin plates, gives the tree a very characteristic appearance in winter, while in summer the Plane-tree, with its large head of dense bright green foliage and with its massive trunk, is a beautiful and majestic shade tree. The native *Platanus occidentalis* is hardy north and *P. orientalis* hardy as far north as Mass., while the southwestern and Mexican species cannot be cult. in the North. From time immemorial the Oriental Plane, which was well known to the ancient Greek writers, has been famous for the large

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